BROOKHAVEN NATIONAL LABORATORY
LASER CONTROLLED AREA
STANDARD OPERATING PROCEDURE (SOP)

This document defines the safety management program for the laser system listed below. All American National Standard Institute (ANSI) Hazard Class 3b and 4 laser systems must be documented, reviewed, and approved through use of this form. Each system must be reviewed annually.

System description: GAM Excimer laser
Location: BLDG 939

LINE MANAGEMENT RESPONSIBILITIES

The Owner/Operator for this laser is listed below. The Owner/Operator is the Line Manager of the system and must ensure that work with this laser conforms to the guidance outlined in this form.

Owner/Operator: See Page 17 for Signatures

Name: A. Burrill/T. Srinivasan-Rao *Signature:* *Date:* 10,sept 2003

AUTHORIZATION

Work with all ANSI Class 3b and 4 laser systems must be planned and documented with this form. Laser system operators must understand and conform to the guidelines contained in this document. This form must be completed, reviewed, and approved before laser operations begin. The following signatures are required.

C. Weilandics

BNL LSO printed name *Signature* *Date*

ES&H Coordinator printed name *Signature* *Date*

APPLICABLE LASER OPERATIONS
☒ General Operation ☒ Alignment ☒ Service/Repair ☐ Specific Operation ☐ Fiber Optics

ANALYZE THE LASER SYSTEM HAZARDS

Hazard analysis requires information about the laser system characteristics and the configuration of the beam distribution system.

LASER SYSTEM CHARACTERISTICS					
Laser Type *(Argon, CO2, etc)*	Wavelengths	ANSI Class	Maximum Power of Energy/Pulse	Pulse Length	Repetition Rate
Excimer	248 nm	IV	20mJ/pulse	Approx 10 ns	250 Hz

☐ **Cryogen Use**

NONE

☒ **Chemicals & Compressed Gasses**

The excimer laser operates on a gas mixture of 0.165% F_2, 3% Kr, 1% He, 15 ppm O_2, balance Ne. This mixture is contained in the approximately 3 L volume of the laser cavity at a pressure of 3200-3600 torr. The laser is filled from a size D premix bottle (2.7L volume at 113 bar). Due to the low TLV of F_2 the laser will be filled in a well ventilated area approved by the CA-D safety officer.

☒ **Electrical Hazards**

The commercial power supply for charging of the thyratron is a factory supplied item. The electrical specifications of the power supply are: Nominal voltage 110-120 VAC, 4 A, 450W. Nominal frequency 47-63 Hz. The laser has a high voltage thyratron used to initiate lasing. This thyratron has a high voltage range of 10-15 kV at 120 Hz.

☒ **Other Special Equipment**

Description *(Equipment used with the laser(s)).*

The laser system as a complete unit includes a small vacuum pump enclosed in the laser case for evacuating the used gas mixture. In addition there is a halogen filter to trap the fluorine gas. The halogen filter is connected to the gas vent inside the laser and is rated for more than 2000 complete laser refills, and approximately 4 times this number of partial refills. The filter is designed to be replaced during factory rebuilds, and is not a user serviceable component.

Laser System Configuration: Describe the system controls *(keys, switch panels, computer controls),* beam path and optics *(provide a functional/block diagram for complicated beam paths)*.

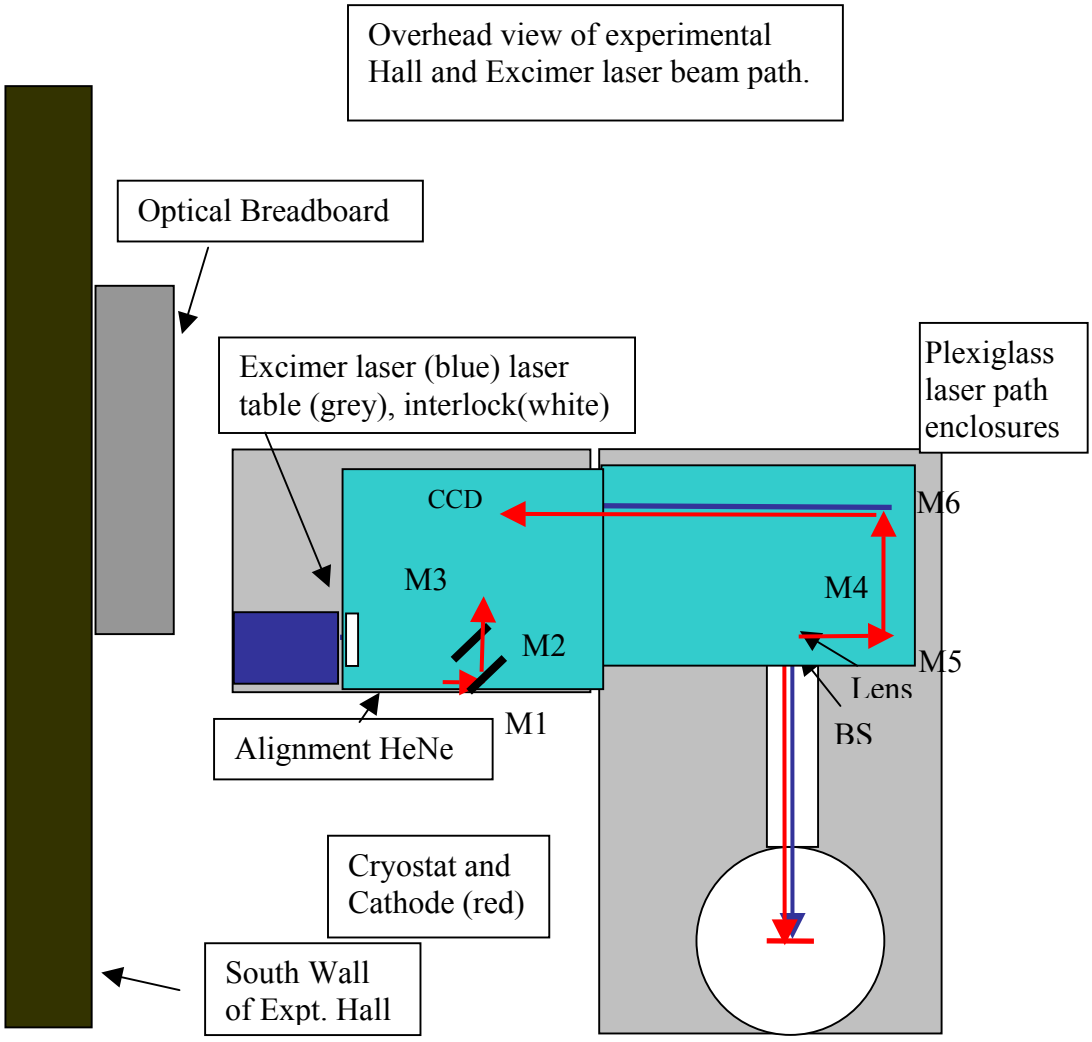
The laser is a commercial (GAM Laser Corp) Excimer laser operating at 20 mJ/pulse and 250 Hz. The output characteristics of the laser are as follows:

Wavelength:	248 nm
Max. Average power:	5 W
Repetition rate:	250 Hz
Spot size:	6 mm x 4mm
Divergence	.5x.1 mrad
Pulse duration:	10 ns

The laser sits on a platform near the end of the SCRF injector beam line, directly opposite the niobium cavity to be cleaned. The laser beam path is completely enclosed in a metal/plexiglas box.

A schematic of the laser beam transport is shown in Figure 1.

Figure 1 Schematic of the laser beam transport for the Excimer laser used to clean the photocathode.



DEVELOP CONTROLS
IDENTIFY ES&H STANDARDS

Recognition, evaluation, and control of laser hazards are governed by the following documents.

American National Standards Institute (ANSI) Standard for Safe Use of Lasers;
(ANSI Z136.1-2000)

Laser Safety Subject Area

Brookhaven National Laboratory Environment Safety and Health Standard: 1.5.3 INTERLOCK SAFETY FOR PROTECTION OF PERSONNEL

ENGINEERING CONTROLS

☒ Beam Enclosures	☒ Protective Housing Interlocks	☐ Other
☒ Beam Stop or Attenuator	☒ Key Controls	
☒ Activation Warning System	☒ Other Interlocks	
☐ Ventilation	☒ Emission Delay	

Describe each of the controls in the space provided below this text. Interlocks and alarm systems must have a design review and must be operationally tested every six months. Controls incorporated by the laser manufacturer may be referenced in the manuals for these devices. **Attach a copy of the design review documentation and a written testing protocol. Attach or keep elsewhere any completed interlock testing checklists to document the testing history.**

Engineering Controls Description:

Beam Enclosure: The beam transport from the exit of the laser to the entrance of the SCRF beampipe is enclosed by a metal/plexiglas box that completely blocks the UV from exiting to the room. Warning signs appropriate to the laser will be posted on, or near the tubing.

Beam Stop: There is a solenoid operated beam stop that is directly in front of the laser. This beam stop is part of the interlock system described below, and remains in front of the laser unless all necessary steps have been taken to make the system ready for operation.

Activation Warning system: The laser is equipped with a key switch, which when turned activates a yellow light on the rear panel to illuminate and also emits an audible alarm for approximately 5 seconds.

Protective Housing Interlocks: The laser is equipped with an interlock on the housing of the laser, as well as a remote interlock on the rear control panel. Attempting to operate the laser without both interlocks engaged will result in no HV being sent to the laser head.

Key Control: The laser system has a key control needed to make the laser operational. This key will be turned off when the laser is not in use to avoid unintentional laser operation.

Other Interlock: The door to the experimental hall is part of the laser interlock system and is connected to a solenoid shutter (beam stop) that is located in front of the laser. If the door is opened or any other part of the interlock system activated this shutter will block the beam (see attached schematic). The interlock system will be tested periodically by the Access Control Group of CAD [E-Cooler Laser Interlock Test Procedure] and the status will be recorded in the logbook kept in the laser room.

Activation Warning System: Warning light outside the experimental hall will be on when the laser is on.

Emission delay: There is a 5 second delay between the key switch and the laser pulse enable.

ADMINISTRATIVE CONTROLS

☒ Laser Controlled Area ☒ Signs ☒ Labels ☐ Operating Limits

The format and wording of laser signs and labels are mandated by BNL and ANSI standards. Only the standard signs are acceptable. Standard signs are available from the BNL Laser Safety Officer.

All lasers must have a standard label indicating the system's wavelength, power, and ANSI hazard class. Required labels must remain legible and attached. The manufacturer should label commercial systems.

Standard Operating Procedures (SOP) are required for laser system operation, alignment, and maintenance. The SOPs need only contain the steps necessary to perform these tasks and identify when and where posting and personal protective equipment is required. SOPs must be approved by the BNL Laser Safety Officer and should be kept with this program documentation.

Administrative Controls Description:

Signs: specifying the gain medium, emission wavelengths, power and repetition rates will be posted both outside the experimental hall and outside the beam enclosure.

Labels: labels specifying the output parameters are posted on the laser itself.

Warning light: outside the experimental hall will be on when laser is on, or the system is open for maintenance and troubleshooting.

CONFIGURATION CONTROL

Prepare and attach a checklist to be used for configuration control of any protective housings, beam stops, beam enclosures, and any critical optics *(mirrors or lenses that could misdirect the beam and result in personnel hazard)*. Include entries to ensure placement of required signs and labels and status of interlock verification. Completed checklists must be posted at the laser location. The checklist does not have to be redone unless there has been a system modification, extended shutdown, or change of operations.

See attachment 2.

PERSONAL PROTECTIVE EQUIPMENT

☒ Eye Wear ☒ Skin Protection

Eye Wear: All laser protective eyewear must be clearly labeled with the optical density and wavelength for which protection is afforded. Eyewear should be stored in a designated sanitary location. Color - coding or other distinctive identification of laser protective eyewear is recommended in multi laser environments. Eyewear must be routinely checked for cleanliness and lens surface damage.
Skin Protection: For UV lasers or lasers that may generate incidental UV in excess of maximum permissible exposure (MPE), describe the nature of the hazard and the steps that will be taken to protect against the hazard.

EYE WEAR SPECIFICATIONS

Laser System Eyewear Identification	Wavelengths	Intra-beam Optical Density	Diffuse Optical Density
KrF Excimer	248 nm	9+	

Eyewear shall be worn during UV alignment and trouble shooting/maintenance

EYE WEAR REQUIREMENTS				
Laser Type *(Argon, CO2, etc)*	Wavelengths	Intra-beam Optical Density	Diffuse Optical Density	NHZ
KrF Excimer	248 nm	6.33(10 sec.)	3(600 sec.)	5.6 meters

Define eyewear optical density requirements by calculation or manufacturer reference and list other factors considered for eyewear selection. The BNL Laser Safety Officer will assist with any required calculations.

1. For invisible beams, eye protection against the full beam must be worn at all times unless the beam is fully enclosed.
2. For visible beams, eye protection against the full beam must be worn at all times during gross beam alignment.
3. Where hazardous diffuse reflections are possible, eye protection with an adequate Optical Density for diffuse reflections must be worn within the nominal hazard zone at all times.
4. If you need to operate the laser without wearing eye protection against all wavelengths present, explain the precautions that will be taken to prevent eye injury.

TRAINING

LASER SAFETY TRAINING

Laser Operators must complete sufficient training to assure that they can identify and control the risks presented by the laser systems they use. Owners/Operators and Qualified Laser Operators must complete the BNL World Wide Web based training course (BNL course #HP-IND-011).

Qualified Laser Operators must also complete system-specific orientation with the system owner/operator. **System-specific training must be documented with a checklist that includes**

- Trainee name and signature
- Owner/Operator signature
- Date
- Brief list of topics covered
  - Review of this program documentation
  - Review of SOPs

All laser safety training must be repeated every two years.
See Attachment 3.

MEDICAL SURVEILLANCE

Operators of ANSI Class 3b and 4 laser systems must complete a baseline medical eye examination prior to laser system operation. Any qualified ophthalmologist may complete this exam. BNL has arranged for this service from the following local physicians:

Dr. Charles Rothberg 331 East Main St. Patchogue, NY 11772	The Ophthalmic Center Dr. Basilice 3400 Nesconset Highway East Setauket, NY 11733	East End Eye Associates Dr. Sherin 669 Whiskey Road Ridge, NY 11961
631 758-5300 $65 per exam	631 751-2020 $60 per exam	631 369-0777 $125 per exam

Personnel using physicians other than those listed must have their examination records forwarded to the BNL Occupational Medicine Clinic.

FEEDBACK AND IMPROVEMENT

Comments and suggestions for improvement should be directed to BNL-Laser Safety Officer, Chris Weilandics (X2593; weil@bnl.gov).

LASER USER QUALIFICATION

Personnel qualified to work with this laser system are listed below. These Qualified Laser Operators must understand the information and conform to the requirements contained in this document. For training and medical surveillance, enter the date of completion.

Qualified Laser Operators:

Basic Laser Training	Job-Specific Training	Medical Surveillance	Printed Name	Signature	Owner/Oper. Initial/date
3/20/03	9/29/03	5/20/85	T. Srinivasan-Rao		
1/8/03	9/29/03	3/26/03	A. Burrill		

See Page 18 for Signatures

Attachment 1
SOP for the SCRF Excimer Cleaning Laser

The laser is a commercial (GAM Laser Corp) Excimer laser operating at 20 mJ/pulse and 250 Hz. The output characteristics of the laser are as follows:

Wavelength:	248 nm
Max. Average power:	5 W
Repetition rate:	250 Hz
Spot size:	6 mm x 4mm
Divergence	.5x.1 mrad
Pulse duration:	10 ns

The laser sits on a platform near the end of the beam line, directly opposite the niobium cavity to be cleaned. The laser beam path is completely enclosed in a metal/plexiglas box.

A schematic of the laser beam transport is shown in Figure 1. Initial alignment of the transport optics will be accomplished using the low power alignment HeNe shown in the figure. Irises are placed along the path of the laser to aid in the alignment process. After initial optical alignment is accomplished using the HeNe, the excimer laser will be aligned with the laser operating at 10 Hz and 5 mJ per pulse (the specified minimum power output for this model laser).

Normal operating procedure:

Under normal operating conditions, the laser beam path, spot size, and energy are measured at the start up and monitored regularly. Once the system's alignment has been verified, normal operation consists of monitoring the output energy using the internal photodiode detector, and monitoring the focal spot of the laser on the cathode by observing the position of the laser on a fluorescent plate (monument), that is an equal distance from the lens to the cathode, using the CCD camera.

I. Laser beam path alignment procedure:

I.1 Observe the position of the UV beam on the irises and monitor the image of the cathode on the monument using the CCD camera.

I.2 If the beam is well centered on the irises and at the correct location on the monument, the alignment is fine. Proceed to measure the spot size.

I.3 If the beam is misaligned, use the irises to identify the mirrors that need to be adjusted. Block the UV beam at the exit of the laser using the retractable beam block. Adjust the mirrors so that the red HeNe beam is well centered on the irises.

I.4 Unblock the UV and check for the co linearity of UV and HeNe beams. If not collinear, turn the knobs in the first two mirrors on the UV beam path to restore colinearity.

I.5 Check the laser spot on the video camera to ensure that the laser irradiates the cathode at the correct location. If not repeat steps 1-5

Initial alignment and Trouble shooting the laser:

During this process, the laser beam enclosure may have to remain open. In such a case, the experimental hall will be considered as restricted area. The entrance door monitored such that when the door is opened, the laser will be blocked. Alignment of the laser path is to be accomplished using the HeNe laser and then the Excimer at its reduced power setting of 5 mJ/pulse and 20 Hz repetition rate. Troubleshooting procedure established by the vendor will be followed. Troubleshooting will be done either by the representative of the vendor or qualified BNL personnel.

II. Alignment:

II.1 Mount mirrors 1-4 in the location that provides the geometry shown in figure 1.(note, the laser enclosures have hinged lids, so all manipulation of optical elements is accomplished by opening the hinged top.)

II.2 Align the HeNe laser onto the four mirrors and adjust the mirrors such that the HeNe laser beam strikes the niobium photocathode.

II.3 Insert the beamsplitter so that a small fraction of the laser light is incident on the monument as viewed by the CCD camera.

II.4 Insert the irises into the beamline and position the irises such that the HeNe passes through the center of each iris.

II.5 Block the laser entry into the electron beam path and SCRF cavity

II.6 Don the appropriate eyewear for the excimer laser at the reduced power setting

II.7 Turn on the excimer laser at the reduced power setting and repetition rate as specified above.

II.8 Align the excimer such that it overlaps the HeNe laser beam path through each iris and is properly centered on the monument.

II.9 Observe the excimer laser beam spot size on the monument using the CCD camera.

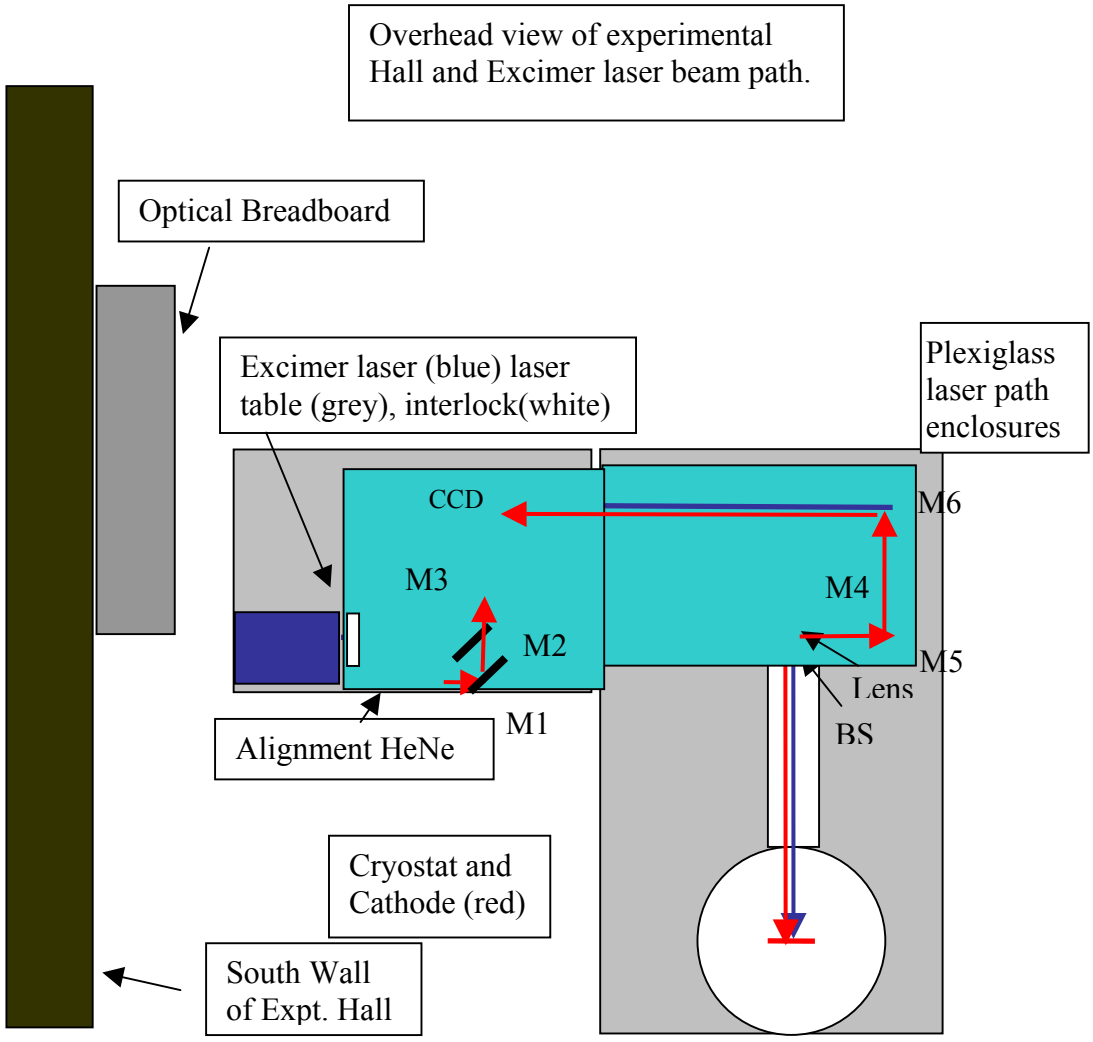
II.10 Adjust the lens position so that the laser spot size meets the requirement

II.11 When ready for measurements, close the plexiglass lid and unblock the entry to the electron beam path.

Filling the Excimer cavity with the premix gas:

In order for the excimer laser to operate it needs to be filled to a pressure of 3200-3600 torr with a gas mixture supplied by the gas manufacturer. This mixture is made up of 0.165% F2, 3% Kr, 1% He, 15 ppm O_2, balance Ne. Due to the nature of the chemicals used in the laser to reach the desired wavelength, the gas cylinder will not be stored inside of the building. Instead the laser will be transported outside to the gas cylinder storage rack where the premix bottle is located and it will be filled there. The purge and fill cycle specified by the laser manufacturer will be followed. During the fill and purge any gas that is expelled from the cavity is passed through a self-contained vacuum pump and halogen filter as described on page 2.

Figure 1 Schematic of the laser beam transport for the Excimer laser used to clean the photocathode.



Training:
All authorized personnel will undergo basic laser training, site-specific laser training and laser eye exam prior to being authorized to handle the laser beam. The basic training is a web-based course covering basic laser hazards and handling procedures. The topics covered in the site specific training would include the specific type and characteristics of the laser being used, appropriate protective wear, precautions to be taken during gas fills, beam enclosures, alignment procedures, low power laser settings and operation of the interlock system. A doctor's report on the eye exam will be on file prior to handling the laser.

Attachment 2

Configuration Control Checklist

The following laser beam configuration controls should be in place during normal operation of the excimer laser for measurements with the niobium cavity (see figure 1 for details).

1. ____ Beam stop shutter in place and operational
2. ____ Mirrors M1-M6 in place and inside of corner enclosures
3. ____ Enclosure box in place with irises open
4. ____ Beamspliter leading to CCD and photodiode in place
5. ____ Laser warning signs in place on door to experimental hall as well as on the Laser and enclosure.
6. ____ Laser interlock and warning light operational and tested
7. ____ Laser cover in place and interlock not defeated
8. ____ All personnel in the experimental hall must be authorized and trained in the use of the laser and must be wearing the appropriate eyewear.
9. ____ Visually inspect the laser beam path for obstructions.
10. ____ Ensure the CCD camera and Photodiode are in place.

Operators Name: (print)_____ date:_____

Signature:_____

Attachment 3

LASER SYSTEM-SPECIFIC TRAINING CHECKLIST

Laser User:	
Laser Owner:	
Laser System:	

Topic	User Signature / Date	Owner Signature / Date
General Laser Safety • Laser classifications • Laser hazards • Maximum permissible exposure • Good practice in the lab		
Interlock Instruction • Configuration • Operation		
Description of Laser Output Characteristics • Wavelength • Pulse energy • Average power		
Associated electrical hazards • Power supply • PMT detectors		
Normal Operation • Power on/off • Shutter operation • Normal experimental configuration • Nominal hazard zone		
Non-Normal Operation • Gross alignment • Troubleshooting		

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Owner/Operator:

Name: A. Burrill/T. Srinivasan-Rao *Signature:* T. Srinivasan-Rao *Date:* 10,sept 2003

AUTHORIZATION

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C. Weilandics	C Weilandics	12/18/03
BNL LSO printed name	*Signature*	*Date*
Asher Ettkin	Asher Ettkin	12-18-2003
ES&H Coordinator printed name	*Signature*	*Date*

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1/8/03	9/29/03	3/26/03	A. Burrill	A Burrill	12/18/03